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voyages to foreign countries. He is seldom in debt. His house is well painted and carpeted, and every thing is comfortable and in good repair. His children are at academies or colleges, and he is a prudent, moral, and temperate man; and could we induce him to leave off whittling shingles, and the immoderate use of tobacco, he is so gentlemanly, that he might sometimes be mistaken for the captain of "a New York liner."

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Art. IV.—1. *Various Papers on Meteorology, and the Laws of Storms*, by W. C. Redfield. American Journal of Science and Arts, Vols. XX, XXV, XXVIII, XXXI, XXXIII. Jamieson's Edinburgh Journal for February and April, 1838. Naval Magazine, Vol. I. English Nautical Magazine, 1839. Journal of the Franklin Institute, Vol. XIX. Blunt's Coast Pilot, 12th and 13th Editions.

2. *An Attempt to develope the Law of Storms by Means of Facts, arranged according to Place and Time, and hence to point out a Cause for the Variable Winds, with a View to practical Use in Navigation.* Illustrated by Charts and Wood Cuts. 2d Edition, with Additions. By Lieut. Colonel W. Reid, C. B., F. R. S., (of the Royal Engineers.) London. 8vo.
3. *The Philosophy of Storms.* By James P. Espy, A. M., Member of the American Philosophical Society, and Corresponding Member of the National Institute, Washington. Boston: 1841. 8vo.
4. *On the Storm which was experienced throughout the United States about the 20th of December*, 1836. By Elias Loomis, Professor of Mathematics and Natural Philosophy in Western Reserve College. Philadelphia: Phil. Trans., Vol. VII., New Series.

About a century ago, Dr. Franklin made preparations to observe an eclipse of the moon at Philadelphia. The execution of his purpose was prevented by a storm from the north and east, which obscured the sky a short time before the moon passed into the earth's shadow. He learned afterwards, to his surprise, that this eclipse had been seen at Boston; and upon comparing the accounts from the other Colonies, he discovered, that our northeast storms obey a fixed law of progress; that they are experienced first in the southwest, and advance towards the northeast.*

The study of this law has led to a series of discoveries in the science of meteorology of the highest value, whether regarded as contributions to knowledge, or as the basis of useful rules for the guidance of conduct; from which the practical man may derive great advantage, and which the philosopher with honorable pride may number among those benefits which his patient investigations confer upon mankind. "*Tant est féconde la méditation d'une loi de la nature.*" These discoveries relate chiefly to the phenomena of storms, — of those dreadful hurricanes especially, which vent their first fury upon the fertile islands of the Caribbean sea, where they originate, and passing thence to the continent, strew the shores of the United States with the wrecks of our rich commerce. By a laborious collation and careful comparison of scattered records, our countryman, Mr. Redfield, obtained a knowledge of their principal features, and consummated his task by the discovery of the general fact, that these storms are comparatively isolated masses of air in a highly disturbed state, the particles of which revolve with such violence as to create the destroying winds called tempests, or hurricanes. Thus the Preacher, in illustrating the vanity of all human pursuits, uttered the language of a correct philosophy. "The wind goeth toward the south, and turneth about unto the north; it whirleth about continually, and the wind returneth again according to his circuits."

The first suggestion, that a storm might be a great whirlwind, was made by Colonel James Capper, of the East India Company's service, in a work on the winds and monsoons of India, published in 1801. He points out the method of investigation since adopted by Mr. Redfield, to whom, however, Colonel Capper's book was entirely unknown. Indeed, this book seems to have attracted little notice before Mr. Redfield's discovery. About the time that the American philosopher was employed in his earlier labors of observing and collecting the observations of others, a similar inquiry was in progress in Germany. On Christmas eve, 1821, after a long continuance of stormy weather, the barometer sank so low in Europe, that the attention of meteorologists was strongly drawn to the circumstance. M. Brande, having obtained the registers kept at this time in various places, came to the conclusion, that, during this storm, the winds blew from all points of the compass towards a central space, where the barometer was, for the moment, at its lowest stand. This conclusion was disputed by Professor Dove, of Berlin, who subjected the observations in the possession of Brande, as well as others, to a new examination, and made it appear, that an explanation of all the phenomena was afforded by the assumption of one or more great rotary currents, or whirlwinds, advancing from the southwest to the northeast.* Before this discussion was known in the United States, Mr. Redfield, by an independent course of investigation, had arrived at the result we have already announced, and his opinion is fortified by facts and cases so numerous and well authenticated, as fully to justify the distinction which Sir David Brewster has accorded to him in the following language. "The theory of rotary storms was first suggested by Colonel Capper; but we must claim for Mr. Redfield the greater honor of having fully investigated the subject, and apparently established the theory upon an impregnable basis." †

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* This eclipse occurred on the 21st of October, 1743. See an "Attempt to fix the Date of Dr. Franklin's Observations in Relation to the North-East Storms of the Atlantic States," by A. D. Bache. *Franklin Journal* for November, 1833.

An inquiry into the nature and operation of these mighty agents of destruction, the sweeping storms on the sea, or the ravaging tornadoes on the land, will prove not less an advantage to humanity than to science. To be able to foretell their approach, and to know their course and action, is to warn the farmer and mariner in time to guard against their effects. And science will be acknowledged to fulfil one of her highest aims, when she adds to those instructions which direct the course of the adventurous seaman over the ocean, the knowledge that will protect him against the rebellions violence of the tributary elements.

Mr. Redfield's researches have made us acquainted with the following general laws. The winds in a great storm, which were once supposed to travel in a direct path pointed out by the vane, do actually revolve about a vertical line or space, which may be regarded as the central axis of motion. Professor Leslie framed a theory accounting for the barometric fluctuations, according to which, the winds in hurricanes were presumed to move in a rectilinear direction, at the rate of one hundred or one hundred and twenty miles an hour. Mr. Redfield has shown, however, that a storm is no longer to be considered as the unequal disturbance of an extended stratum of the atmosphere, but as a vast whirlwind, or vortex, approaching to a cylindrical form, throughout which the motion of the air is rotary. It is not one wind, but a combination of winds from all quarters.

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* *London and Edinburgh Journal of Science*, Nos. 67, 68.

† *Philosophical Magazine*, Vol. XVIII., 3d Series, p. 515.

> "Una Eurusque, Notusque ruunt, creberque procellis
> Africus."

These whirlwinds, or aërial vortices, have a progressive movement, that carries forward the whole body of the storm, apart from the internal motions, which cause its violence. This progressive movement depends upon the prevailing currents of the upper air, and varies from twelve to thirty miles an hour. Such, at least, is the rate of progress of those storms examined by Mr. Redfield. He is aware, however, that some storms appear to be local, and nearly stationary, whilst others move with greater rapidity.

The rotation of the air in the body of the storm is, on the north side of the equator, from the right to the left, or contrary to the movement of the hands of a watch; and, in southern latitudes, from the left to the right, or with the hands of a watch. Its violence increases towards the interior; but in the centre is a space where the winds seem to lose their force. This calm in the middle of a heavy storm is well known to seamen, as the forerunner of a dangerous and violent shift of wind. The barometrical changes first noticed by Mr. Redfield are remarkable, and serve to indicate to the observer the portion of the storm that he occupies. The arrival of the storm, as is well known, is preceded by a fall of the mercury. Mr. Redfield has found, that this fall increases as the storm passes over, up to the central space, where it attains its maximum; the barometer then begins to rise, and gradually mounts as the latter section of the storm recedes. These changes, which are proofs of a rotary and progressive movement, are very valuable to seamen, particularly in pointing out the central calm, the deceitful character of which has, no doubt, caused the wreck of many vessels. The extent of the storm, or of the region over which its influence is felt, Mr. Redfield believes to vary from one hundred to five hundred miles. Those which originate in the tropics increase in diameter, and diminish in violence, as they proceed towards the poles ; and it is suggested by Colonel Reid, that the gales become huddled together as the meridians approach each other, and are so complicated in high latitudes by their rapid succession, that it is not easy, during the season of storms, to identify a particular one.

Mr. Redfield's attention was first called to the hurricanes of the West Indies, the fatal visitations of which are so well and mournfully recorded in the shipping lists.* Availing himself of the various sources of information, he was enabled to pursue the track of a storm from the place of its first appearance, to some point far to the east in the North Atlantic ocean, where its forces, like those of the Gulf Stream, were weakened by diffusion. The charts of the hurricanes show, that they take their rise in the vicinity of the Windward islands, and proceed in a northwesterly course, until they approach the continent of America, where, between the twenty-fifth and thirty-fifth degrees of latitude, they change their path to the north and east, inclining gradually to the east. Their course then becomes nearly parallel to the coast, and sometimes their influence is felt on the whole Atlantic shore, from Cape Florida to Halifax.

One of the hurricanes of August, 1830, has been traced by Mr. Redfield in its daily progress, by means of the journals and reports of voyagers, from near the Caribbee islands to the coast of Florida and the Carolinas, and thence to the banks of Newfoundland, a distance of more than three thousand miles, which was passed over by the storm in six days, at the rate of about twenty-one miles an hour. The duration of the most violent portion of this gale, at the different points over which it passed, was about twelve hours ; but its entire duration was, in some places, twice that period. The breadth of the storm, therefore, may be estimated as between two hundred and fifty and four hundred miles, — the duration depending upon its extent and the velocity with which it moves.

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* The West India hurricane season is reckoned from the 15th of July to the 15th of October. During this period, premiums of insurance, that are usually 2½ *per cent.*, rise to 4, and 6 *per cent.* The hurricane region is included between the 10th and 28th degrees of north latitude, and the 58th and 86th degrees of west longitude.

On that portion of the track nearest to the American coast, or the farthest inland, if the storm overlies the continent, the wind begins to blow from the eastern or northeastern point of the horizon, and veers by the north to the northwest, where it terminates. These are known as the northeast storms of the Atlantic States, which are most severe in the beginning, are attended with rain or snow, and generally end with a wind at the northwest, bringing fair weather.

Such are the leading general facts, ascertained by Mr. Redfield, concerning the operations of nature in great storms, particularly those of the United States, and the hurricanes of the West Indies. They are carefully deduced from observations and experiences endlessly multiplied ; and the leading proposition of the rotary motion is fortified by so wide an induction, that we have no hesitation in speaking of it as a truth satisfactorily demonstrated. Mr. Redfield's views are corroborated by Professor Dove, of Berlin, who, without any knowledge of Mr. Redfield's labors, arrived at similar conclusions at about the same time. It is not to be supposed, however, that the rotary storm, though probably the greatest, is the only disturbing cause of the regular atmospheric currents.[*] Mr. Redfield, whose aim has been, "first, to resolve particular facts into other facts more simple and comprehensive ; and, secondly, to apply these general facts (or, as they are usually called, *laws of nature*) to the synthetical explanation of the phenomena "[†] of storms, was not anxious to indulge, in his earlier papers, in speculations concerning the *origin* of the phenomena, whose active force he was investigating. Science has not yet determined the part, (probably an important one,) which electricity takes in their production.

But it is less difficult to assign a cause for the mechanical disturbance of the atmosphere, which will result in the formation of aërial whirlpools. Maupertuis, while engaged in his geodesic operations at Tornea, observed that, on opening the door, the external air immediately produced a whirlwind in the room, which was discernible by means of the con densed vapor. On an occasion in St. Petersburg, when a crowded assembly were suffering from the closeness of the room, a gentleman broke a window for relief, and the air rushing in, formed a visible condensation of snowy matter, having a revolving motion.* It appears, from these anecdotes, that, if a body of air in a quiescent state, at an elevated temperature, and highly saturated with vapor, be suddenly penetrated by a cold current, an aërial vortex will be instantly formed.

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[*] We should be glad to present our readers with the outlines of Professor Dove's "General Theory of the Winds," and of the admirable essay of Mr. Brown (*Phil. Mag.*,) in which the views of Daniell are so extended as to embrace hypotheses of the general currents of the atmosphere. But we must keep within the narrowest limits of our subject, — "vapors, and clouds, and storms."

[†] Stewart's *Elements*.

Mr. Redfield has met with an able and efficient coadjutor in Lieutenant-Colonel Reid, of the Royal Engineers, who, having been employed at Barbadoes in reëstablishing the public buildings blown down in the hurricane of 1831, had already conceived an interest in the study of the nature of storms, when he read a paper by Mr. Redfield in "Silliman's Journal," for April, 1831. In his valuable work, he has not only laid down in a beautiful manner and with scrupulous fidelity the *data* furnished by Mr. Redfield, but he has also collected numerous accounts of other storms in both hemispheres. To his industry in compiling and arranging curious and important facts must be awarded high praise ; but to his modesty and candor no praise, however high, can do more than justice. Upon all topics which he discusses, he has been studious to collect authentic information, and whenever he has been carried into the field of conjecture, he has advanced with that sedate caution and steady regard for certain knowledge, undisturbed by the vanity of speculation, which become the philosophical inquirer. Colonel Reid was the first to illustrate the reverse motion of storms in the southern hemisphere. The most interesting of his records upon this point are those of the storm of March, 1809, encountered by the fleet of the East India Company, under the convoy of the *Culloden*, bearing the flag of Rear Admiral Sir Edward Pellew, the first Lord Exmouth. It has left a deep impression upon many minds in England by the great loss of life and property it occasioned.

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* Harvey's *Treatise on Meteorology*, — *Encyclopædia Metropolitana.*

The fleet had crossed the equator, and sailed on its homeward passage with fine weather, until the 11th of March, when the gale came on. They were then in the vicinity of the islands of Rodriguez and Mauritius, a region which, on the opposite side of the line, corresponds to the West Indies in its stormy character. On the 14th, the fleet was dispersed, and this circumstance afforded the means of obtaining simultaneous observations of the wind in different sections of the storm. After travelling obliquely to the trade-wind, from the east to the west, inclining southerly, the storm recurved at the twenty-fifth and thirtieth degrees of latitude, and went off to the *south*-east, in remarkable conformity with the manner in which the hurricanes of the northern hemisphere pass off to the *north*-east. The brig of war *Harrier* was lost, and four of the East India Company's ships, the *Lady Jane Dundas*, the *Jane*, *Duchess of Gordon*, the *Calcutta*, and the *Bengal*. The four latter were seen for the last time on the 14th, and probably foundered near the centre of the storm, towards which they were then steering.

Colonel Reid has also accompanied Mr. Redfield in his inquiry into the phenomena of water-spouts and whirlwinds. He considers it by no means certain, that the same law of nature produces the small whirlwind and the great storm. We know of no authentic observation, however, except that made by Colonel Reid himself, at Bermuda, which combats the opinion of Mr. Redfield, that the course of rotation is the same in both. The whirling motion of the air satisfactorily accounts for the fall of fish,* and showers of sand, seeds, blood, (a misnomer for red earth, probably,) and salt rain, of which many instances are related both by Colonel Reid and Mr. Espy. Colonel Reid has also applied the diminution of the atmospheric pressure in the centre of storms to explain the extraordinary high tides, and consequent inundations, that often prove more disastrous than the wind. A fall of two inches in the barometer indicates a diminution of one fifteenth in the atmospheric pressure, which would cause the sea under it to rise two feet. A wave of the sea, answering to the atmospheric wave, may move onward at the rate of the storm's progress, accompanying it in its course, and its height will depend upon the reduction of the atmospheric pressure, modified by the revolving power of the wind. When an impulse, thus acquired, has been maintained for some distance, a current will be created, similar to the tidal wave, and of sufficient strength, when added to the flood tide, to cause the inundations that often occur in flat lands. A storm five hundred miles in diameter, carrying with it the diminished pressure of one fifteenth of the column of mercury, seems adequate either to arrest or accelerate existing currents, or to create new ones. Sir Thomas Hastings saw, during a rapid fall of the barometer, at Portsmouth, an ebbing tide stop, and return to the flood, before its period had elapsed. A well attested fact like this proves the correctness of the Colonel Reid's views.

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* A curious case of the fall of fish in a storm is recorded in *The Athenæum* for October, 1840. It occurred in the Madras Presidency, sixty or seventy years ago, and a sufficient number was gathered to make a curry for the General's table.

"Piscium et summa genus hæsit ulmo
Nota quæ sedes fuerat columbis."

"The apparent connexion of storms with electricity and magnetism" is a subject of the deepest scientific interest. The quantity of electricity developed in violent storms is very great, and has, at times, if the accounts can be relied on, affected the needle to such a degree, that it ceased to be of any use. Colonel Reid ascertained, by experiment, that the two poles of the magnet, in conjunction with the voltaic battery, moved in a manner corresponding to the revolution of hurricanes in the northern and southern hemispheres. Great storms of periodical recurrence are confined, as is well known, to certain parts of the globe ; and it is a curious fact, that the meridians passing through the two north magnetic poles run also through the Chinese sea, and near the Caribbean sea, — the regions of typhoons and hurricanes ; and that here, the magnetic intensities upon Major Sabine's chart of isodynamic lines are strongly marked, whilst at St. Helena, where a gale is rarely known, the intensity observed by Captain Fitzroy is 0.84, "the lowest denomination recorded."

But we resume the examination of the rotary law of storms, which, as we before observed, is the *general* fact, confirmed by Professor Dove and Colonel Reid, deduced by Mr. Redfield from the particular facts he has accumulated. The question is, Do the particular facts sustain Mr.

Redfield's law, and does the law account for the phenomena of storms included in its classification ? The negative answer is stoutly maintained by Mr. Espy of Philadelphia, whose work on the "Philosophy of Storms" stands at the head of our article. Mr. Espy has been known to the public for many years as a writer in the "Franklin Journal" upon various subjects of science, but chiefly upon meteorology. In 1836,* he published a series of essays, containing a theory of the formation of clouds, and rains, the aërial meteors known by the names of storms, tornadoes, whirlwinds, waterspouts, &c., some of the elementary principles of which are to be found in his earlier papers.† The greater part of the "Philosophy of Storms" is a republication of his essays and papers in the "Journal."

His theory is at once simple and comprehensive, and, as "the probability of a hypothesis increases in proportion to the number of the phenomena for which it accounts, and to the simplicity of the theory by which it explains them,"‡ if the facts cited by Mr. Espy were to be received without hesitation, we should be as ready to yield our entire assent to its propositions, as we are to admire the ingenuity displayed in its invention. Mr. Espy repeats the doctrine of Brande, that the winds in a great storm rush impetuously from all parts of its outer boundary, either towards a single centre, or, when the storm is of an elongated form, towards a diametrical line which is the longer axis. Whether this opinion be borrowed from Brande or not, it is a necessary consequence of the new theory. To support this view, Mr. Espy also appeals to facts, and to the very facts adduced by Colonel Reid and Mr. Redfield, as evidences of the rotary motion. He has been active in collecting records for himself, but the storms of 1780 and 1837 are presented in his book as most striking illustrations of his theory, and their application is the more conspicuous, as they are selected from Colonel Reid.

It behooves us, then, to examine this question, and, to render the subject more intelligible, we will make the necessary projections. In doing this, it will be our object to test Mr. Espy's merit as an observer and recorder of facts ; hereafter, we shall discuss his theory. The following figure represents the progressive whirlwind of Mr. Redfield, the arrows between the two outer circles showing the direction of the wind according to his law. The dotted arrows mark the central direction of the wind, as maintained by Mr. Espy.

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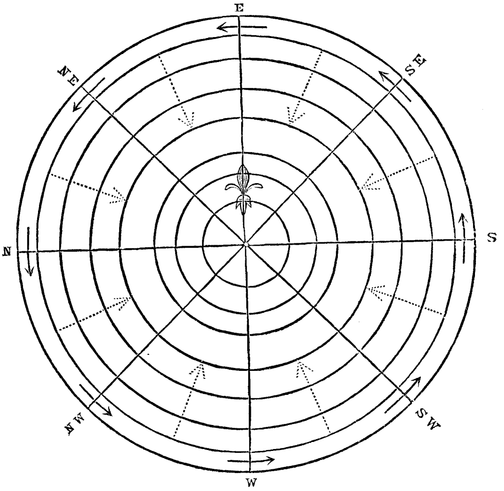
* *Franklin Journal*, Vols. XVII., XVIII.

† *Franklin Journal*, Nov., 1833, and Jan., 1835.

‡ Stewart's *Elements*.

Due North.



It will be remarked, that the wind on the north side of Mr. Redfield's whirlwind blows from the east ; on the south side, from the west ; on the east, from the south ; and on the west, from the north. The centripetal storm of Mr. Espy, as shown by the dotted arrows, blows from the point indicated by the compass direction, in the line of the radius, and his wind is always at right angles to Mr. Redfield's. It would not seem very difficult, then, to make up our judgment on this matter, if we were supplied with correct statements of the direction of the wind in different parts of the storm at the same time.

The most valuable information gathered by Colonel Reid is that relating to the hurricanes of October, 1780, the most terrible recorded in West Indian history. Three great storms happened in the same month. The first destroyed the town of Savanna-la-Mar, and wrecked the British frigate *Phenix.* The second, and by far the severest, desolated the island of Barbadoes, and inflicted great losses upon commerce and upon the British fleets. The third dispersed the Spanish fleet under Solano, in the Gulf of Mexico, after it had sailed from Havana to attack Pensacola. The faithful method adopted by Colonel Reid, of printing all the accounts in detail, affords to every one the same means of arriving at the truth. England, being then at war, had large squadrons in the West Indies, and on the American coast, and this circumstance multiplied the facilities for tracing these gales.

Sir Peter Parker commanded in the West Indies, and Sir George Rodney was off New York in the *Sandwich*. In the squadron of the former, eight ships were lost, and their crews nearly all perished, and seven vessels were dismasted. In that under Rodney, five vessels were lost, and nine were dismasted, or severely damaged. Savanna-la-Mar was destroyed, the islands of Barbadoes, St. Vincent, St. Eustatia, Dominica, Grenada, and Martinique suffered dreadfully. Twenty-five or thirty thousand persons are known to have perished on the islands, besides the crews of the men-of-war already mentioned, and of numerous trading vessels which were wrecked. At Grenada alone, "nineteen sail of loaded Dutch ships were stranded and beaten to pieces." Six ships of war were anchored at the careenage of St. Lucia, when the gale began, and five of them were driven to sea, and returned to port in the most helpless condition. The language of poetry bears a literal interpretation.

"And anchored navies from their stations drive,
Wild as the winds, across the howling waste
Of mighty waters."

At Barbadoes, the family of the governor were obliged to take refuge in the cellar, the wind, in spite of every precaution, having forced a passage into all parts of the house, and torn off most of the roof.

"From this asylum, they were soon driven out; the water being stopped in its passage, having found itself a course to the cellar, they knew not where to go. The water had risen four feet, and the ruins were falling from all quarters. To continue in the cellar was impossible; to return to the house equally so. The only chance left was making for the fields, which at that time appeared equally dangerous. It was, however, attempted; and the family got to the ruins of the foundation of the flag-staff, which soon after giving way, every one endeavoured to find a retreat for himself. The governor, and the few that remained, were thrown down; and it was with great difficulty they gained the cannon, under the carriage of which they took shelter. Their situation was deplorable; many of the cannon were moved; and they had reason to fear that the one under which they sat might be dismounted and crush them by its fall, or that some of the ruins which were flying about might put an end to their existence; and to render the scene still more doubtful, they were near the powder magazine. Anxiously did they look for the break of day, flattering themselves that with the light they would see a cessation of the storm; yet, when it appeared, little was the storm abated. Nothing can be compared with the terrible devastation that presented itself on all sides; not a building standing. The trees, if not torn up by the roots, were deprived of their leaves and branches; and the most luxurious spring changed, in this one night, into the dreariest winter."*

Such are the awful scenes which the study of this subject leads us to contemplate. One anecdote illumines for a moment the dark gloom. The *Endymion*, *Laurel*, and *Andromache* were to the east of Martinique, and on a lee shore. The *Endymion* just cleared the northeast point of the island; but the two latter vessels were wrecked, and twenty-five of the crew of the *Laurel* alone were saved. These men, of course, were made prisoners. They were sent by the Marquis de Bouillé to the British governor at St. Lucia, with a letter, saying that he could not detain them as prisoners from the chances of a catastrophe common to all.

"How far that little candle throws his beams!"

In the first storm, on the third of the month, Mr. Espy has selected the time when the centre is supposed to have passed over Lucia bay, about six o'clock, P. M. The records of the storm at this moment are very incomplete; all winds to the west of south and north are wanting; that is, for one half of the circle, and those on the other half are confined to a small space. This hurricane, we incline to believe, originated on the island of Jamaica. It is first heard of at Port Royal, where it raged more than twelve hours before it reached Savanna-la-Mar. This fact, which Mr. Espy omitted to notice, is entirely inconsistent with his theory; for, according to that, as the wind was from the southeast, the centre of the storm should have been far to the north of Jamaica, before the first part reached Savanna-la-Mar. Neither has Mr. Espy given the exact directions of the wind upon his sketch; his south is nearer south by west, and the south-southeast at Port Royal is southeast. These may be errors of the engraver, but they favor his views. But the *data* of the storm are not sufficient at this point to authorize its use as a demonstration of either theory.* When we pass to the two next recorded stages of its progress, where it overtook Admiral Rowley's squadron, and the ships belonging to Sir George Rodney's fleet, the whole body of the evidence is in harmony with the rotary law, and irreconcilable with the rectilinear hypothesis. As Mr. Espy has avoided these tests, we will not dwell upon them, but proceed to examine the hurricane of the 11th and 12th, at the point chosen by himself. It is to be observed, however, that whilst Mr. Redfield and Colonel Reid give charts of the whole track of the storm, Mr. Espy limits his projections to one period. If his principle be correct, it applies equally to all periods, and to no one more than another. The following sketch is copied from Mr. Espy's book.†

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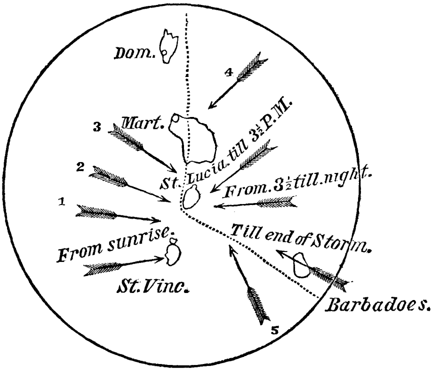
* *Gentlemen's Magazine* of 1780. Reid, pp. 347, 384.

"Chart of the great Barbadoes hurricane, October 11th, 1780, showing the course of the wind at 6, P. M.



1. Montagu, from 6 to 8, P. M. 4. Endymion, from P. M. of the 10th to 12th.
2. Amazon, at 2, P. M. 5. Albemarle, from 4½ P. M. till next day.
3. Alcmene, from 5 till 9, P. M.

"The dotted line is the course which the centre of the storm moved in."

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* Among the documents relating to this storm is a letter from Lieutenant Archer to his mother, giving an account of the loss of the *Phenix*, written in a very graphic style, and filled with details of touching interest, such as created the universal popularity of Mr. Dana's "Two Years before the Mast." It is too long to quote, but we recommend its perusal.

† Espy, p. 199.

These arrows point inwards to a central space ; but when we have made the necessary corrections, the character of the testimony will be changed. The wind of the *Montagu* which Mr. Espy has put down W. by N. is really N. N. E.* The wind of the *Amazon* instead of being N. W. is N. E.† There is a palpable error in the log of the *Alcmene* ; for the wind is marked N. W. when the ship's head in the adjoining column is N. W. also ;‡ the "Remarks," as well as the log of the *Amazon*, which vessel was very near the *Alcmene*, show that N. W. is a misprint for N. E. The wind of the *Endymion* is not N. E. as given by Mr. Espy, but E. N. E. § Mr. Espy's position of the *Albemarle* is wrong ; that ship was further to the north and east than he represents her.‖ At St. Vincent, the wind was a little to the west of N. W. and not W. by S. The winds at St. Lucia, so minutely noted as to time, are not to be found in Colonel Reid's documents.¶ The wind at Barbadoes is loosely given, and at long intervals,** so that it is impossible to determine the precise direction at 6, P. M. We shall not make use of it. Finally, Mr. Espy has omitted the *Vengeance* and the *Egmont* altogether, though they were within the space included in his chart. Of the nine arrows, then, in Mr. Espy's projection, eight are positively erroneous, and the ninth (Barbadoes) is uncertain ; two other *data* of equal importance are omitted. In the following projection, the arrows are pointed the *right* way.

The reader will perceive, that the mass of air between the circles exhibits a uniform rotary character. In any particular section, the whole tendency is from right to left, and in no instance is it reversed. The course of the wind sometimes deviates a little, as at the *Albemarle* and *Endymion*. The difficulty of observing the exact direction of the wind in a tempest, both at sea and on shore, particularly in the former case, where the motion is violent and unceasing, must be taken into consideration. The winds, too, in their fierce contention will be diverted from regular action. It is rather to be wondered at, that so slight a variation from a steady motion in rotation should be found in so many different ac-

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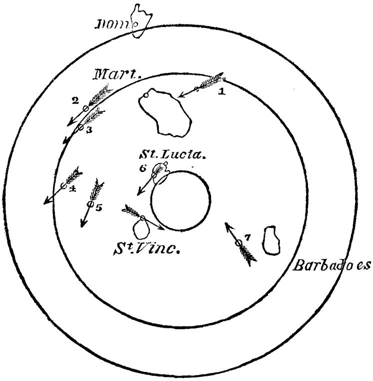
* Reid, p. 365. † *Ibid.* p. 367. ‡ p. 357.

§ p. 371. ‖ Chart 9. ¶ Chap. 8, *passim*.

** There is a contradiction between the log of the *Albemarle* and the account in the *Gentleman's Magazine*, as to the direction of the wind at 10 o'clock of the 10th. The *Albemarle* must be right; otherwise she could not have gone to sea, and doubled the point of the island.



1. Endymion. 3. Amazon. 5. Montagu. 7. Albemarle.
2. Alcmene. 4. Egmont. 6. Vengeance.

counts and situations. Several of the arrows point in direct opposition to the convergent theory; especially those at St. Vincent, and near Barbadoes. The latitudes of these places are nearly the same; the wind at one is northwest, and at the other southeast; according to Mr. Espy, therefore, the middle of the storm would be north and south of the same parallel, at the same time. At the various stations, the wind went round the compass in conformity with the law of rotation. We may refer particularly to the report of the intendant of Martinique, to the *Endymion*, and indeed to all the vessels. To follow the storm in its whole progress, and point this out in detail, would occupy too much space.

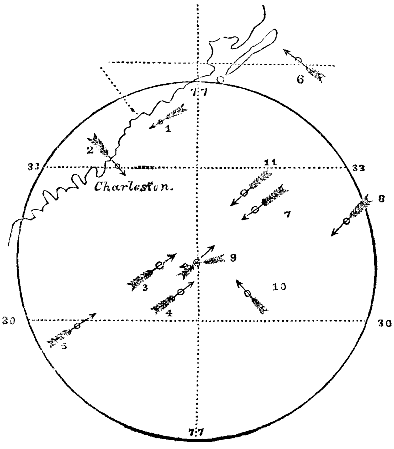
This hurricane of the 11th of October is altogether the most affecting of those mentioned in Colonel Reid's work. It is also the most complete in its annals. It is curious to read the musty old log-books, which were laid upon the shelf sixty years ago, without the least probability that they would ever see the light again. Written with technical conciseness, they appear to exhibit a singular insensibility to the perils and hardships they briefly record. Here and there the cry of the strong swimmer in his agony echoes in our ears; but the notice both of the living and the dying is the mere mention of a fact, and the lament over many

> "a brave vessel,
> Who no doubt had noble creatures in her,
> Dashed all to pieces," —

is confined to the hasty condolement of an official despatch.

Another storm mentioned in Colonel Reid's book, and selected by Mr. Espy as an illustration of his theory in opposition to the rotary law, is that of the middle of August, 1837. He has undertaken to give the position of the storm at noon of the 18th, the period of most rapid change. We have no hesitation in saying, that it is impossible to ascertain the directions of the wind at this hour, for all the vessels on his chart, with any approximation to certainty. For instance, "The *Delaware*, on the 17th, lat. 31° 30′, long. 76° 20′, had a severe gale E. S. E. and then W., which continued till the 20th" ; * and it is from loose statements like this, that, without any qualification, he determines the position and wind of many of the vessels at noon of the 18th, as if they had been expressed at that precise moment. The following is Mr. Espy's projection. †

" Position of storm at noon on the 18th of August, 1837.



1. Wind at Wilmington, P. M. of 18th.
2. Oglethorpe on 18th.
3. West Indian all 18th, from 2, A. M.
4. Rawlins, all 18th, from 2, A. M.
5, Ida, all day of 18th.
6. Penelope, on P. M. of 18th.
7. Yolof, till 8, P. M. of 18th.
8. Westchester, on 18th.
9. Duke of Manchester, till P. M. of 18th.
10. Delaware, on 17th, and probably on 18th, changing round to westward on 20th.
11. Cicero, on 18th."

We have to remark concerning it, that the wind at Wilmington is right; that the position given to the *Oglethorpe* is incredible, as it puts that brig only thirty-five miles from Cape Roman, in the neighbourhood of the shoals of Cape Fear, four degrees inside of Cape Hatteras, and four and a half degrees to the westward of the Capes of the Delaware; yet she was reported in a New York* paper, and, no doubt, was bound to a Northern port. It is not only incredible, that she should have run into this dangerous position, but it seems impossible. She was in a northwest gale on the 13th,† and on the 18th, against which she must have proceeded in order to arrive at this place.

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* Espy, p. 237.

† *Ibid.* p. 238.

The *West Indian* is placed accurately enough. The wind of the ***Rawlins*** is north, instead of S. W. as Mr. Espy puts it. There is no authority for the wind of the *Ida*; it is described in her log-book as "veering from N. E. to S. W."‡ The *Penelope* is right. The log-book of the *Yolof* shows no wind until after 8, P. M. of the 18th.§ According to the brief newspaper paragraph, which is the only authority,|| the *Westchester* was in the same latitude in *a gale of wind* for two days. This is absurd, and as there are no means of determining her correct place, she is rejected. Mr. Espy has put down the *Duke of Manchester* in a wrong position. She differs from the ***Rawlins*** more than two degrees in her latitude;¶ but on the chart they are brought near together, and their winds (that of the latter being misstated) are drawn so as to converge. We have already quoted the report of the *Delaware*; it evidently cannot serve any purpose that aims at accuracy. The *Cicero* is also rejected; her winds agree well enough with the rotary law, but are not sufficiently specific.** Lastly, the ships *Sophia* and *Westbrook*, the bark *King Philip*, and the brig *Mary*, within the influence of the storm, are omitted on Mr. Espy's chart.††

We subjoin a *correct* view of the storm on the 18th, to which the same remarks will apply as to our first amended projection.

In addition to the facts given above, Mr. Espy has cited the accounts of many hurricanes and gales collected by himself, as proofs of his theory. It is, of course, out of the

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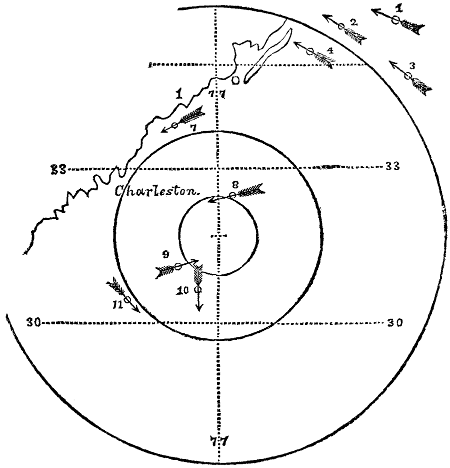
* Espy, p. 238.
† Reid, p. 88.
‡ *Ibid.* p. 102.
§ *Ibid.* pp. 106, 107.
|| Reid, p. 86.
¶ *Ibid.* p. 116.
** Espy, p. 237.
†† Reid, chap. 5.



1. Sophia.
2. Mary.
3. Westbrook.
4. Penelope.
7. Wilmington.
8. Duke of Manchester.
9. West Indian.
10. Rawlins.
11. King Philip.

question to enter upon a critical examination of them here. We will observe, however, that Mr. Espy's summation of the "labors of the joint committee," and his conclusions therefrom are wholly unsatisfactory. In the storm, too, of the 16th, 17th, and 18th of March, 1838, of which Mr. Espy gives a chart showing the probable limits of its extent, we are required to admit, that the wind blew inwards from the borders of the storm universally; when, in fact, of sixteen or eighteen arrows touched by the limiting circle, or included within it, one half, namely, those numbered 1, 12, 14, 17, 18, 21, 27, 28, 30, do not point inwards. Mr. Espy, before the British Association, quoted the storm of January, 1839, in Great Britain, as sustaining in all its phenomena the theoretical principles he was advocating. This storm has since been again examined by Mr. Hopkins of Manchester, with information furnished by Mr. Smith of Liverpool, in a pamphlet comprising one hundred and forty-one accounts, taken from the local newspapers in various parts of Ireland, Scotland, and England. He did *not* find Mr. Espy's "converging streams rushing towards a centre."

The accounts of storms taken from the public prints are generally vague, meagre, and unsatisfactory. Their object is not to convey accurate meteorological knowledge, but to relate local and commercial news. There are two modes of treating these accounts; either to present them entire, as Colonel Reid and Mr. Redfield have done, or, like Mr. Espy, to make selections. When the latter course is pursued, there is danger of considering those facts as the most reasonable and credible, which accord with the preconceived opinions of the theorist, whilst those at variance with them are likely to be rejected as imperfect and irreconcilable with an assumed law of nature. Even such as are accepted may be perverted by prejudice, or a want of proper prudence in guarding against its influence. The numerous errors of Mr. Espy that we have just exposed, render these remarks peculiarly applicable to him. They seriously impair our confidence in his accuracy as an observer, or recorder of facts; in which light we have hitherto considered him.

We may dispense with any labored argument to show, that if there be a fixed law of nature, according to which those storms act, that constitute the seaman's worst dangers, the knowledge of it will prove of infinite importance in preserving the lives and property exposed to hazard in commerce. It is for this reason, that we have extended our criticism further than may be altogether interesting to the general reader. The result is, that we find the law of Mr. Redfield fully sustained; and we see, that the Royal Society * and the British Association † concur in his views. Mr. Redfield, however, has modified his first conception so far as to admit an inward and upward tendency, and a consequent spiral action, in the winds that compose the body of the storm.‡ This expresses our own view more completely. A rotary motion, if continued a sufficient length of time, must, we conceive, finally terminate in a spiral revolution. The centrifugal action tends constantly to heap up the air, and increase its density, upon the outer borders of the storm, and the increased density occasions an inward pressure. We may suppose these two forces to be, for a time, equally balanced. But the rotary movement experiencing retardation

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* *Instructions to the Officers of the Antarctic Expedition,* Phil. Mag. Vol. XV, 3d series.

† Professor Forbes's Supplementary Report.

‡ Paper read by Mr. Redfield before the Philosophical Society at Philadelphia, January 15th, 1841.

from friction at the surface of the earth, and from the reaction of the denser medium constantly becoming greater, the centrifugal force is weakened, and when it is reduced so much that the inward pressure gains the ascendancy, as it must do in the end, the spiral revolution is established. The greater height of the barometer at the borders of the storm than in the centre, verifies the existence of an increased density.

Mr. Redfield has found a warm opponent in Dr. Hare, of Philadelphia,* whose strictures also extend to Professor Dove.† As he has chosen to misunderstand and misapply the Professor's expression of a "rotary cylinder," and to insist accordingly, that the outer portion of the storm should be found to move with the greater rapidity, as if the expression were intended to represent the storm as a solid of revolution, he has spared us the trouble of an argument. Dr. Hare's objections are chiefly of a speculative kind. The best answer to them is to be found in the judicious language of Mr. Redfield.

> "If the supporters of a rotative or whirlwind action in tornadoes and hurricanes had chosen to maintain their cause in a speculative manner, the case might have been different. But when their facts and results were offered on the basis of direct observations, which had been set forth in many cases, with particularity and precision, it seems like a waste of words to assail these observed phenomena and results with strictures and objections of this character; volumes of which can never equal in value the direct observations which may be made of the phenomena of a single storm." ‡

Before we conclude this division of our subject, we must advert to the rules drawn up by Mr. Redfield for the government of the seaman when he encounters a revolving storm.§ They are prefaced by observations explaining its principal phenomena, and such general features of it as appear to be established. They are the honorable and valuable results of arduous and successful investigation. A certain degree of intelligence is requisite for their proper application, but they are simplified as far as the topic will admit. That they will prove beneficial to navigation, we have no doubt. The mariner will learn from them to avoid a storm, or, being involved in one, to escape from the destructive violence of the central portion. Surely, that person is to be ranked among the benefactors of mankind, who has lessened the perils of the sea, and added to the security of commerce.

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* *Phil. Mag.* Vol. XIX.; also *Silliman's Journal.*

† *Silliman's Journal,* Vol. XLIII.

‡ *Ibid.*, Vol. XLIV.; Notice of Dr. Hare's "Strictures," &c. Mr. Redfield, in his "Meteorological Sketches," (*Silliman's Journal,* Vol. XXXIII., No. 1,) has presented some theoretical views concerning the prevailing currents of the atmosphere, which will not, we apprehend, receive the entire sanction of the scientific community.

§ *Silliman's Journal,* Vol. XXV.; Blunt's *Coast Pilot.*

It remains for us to discuss Mr. Espy's theory. Before doing so, it will be just to make a hasty review of some of those principles established by the skilful experiments of Dalton, Daniell, and others, upon which it is founded. The experiments of the former upon the rarefaction and condensation of air in the receiver of an air-pump, similar to those made by Mr. Espy in his *nephelescope*, led him to discover the effect of the latent heat of vapor in raising the temperature of the atmosphere. The conditions of the experiments were varied, by using air in the different stages, from extreme dryness to a state of saturation ; the thermometer suspended in the middle of the receiver experienced a fall, which was at its maximum with the dry air, and decreased according to the increase of moisture. Dalton has stated this result as follows : " Suppose that a part of the atmosphere contained one fiftieth of its weight of aqueous vapor, and that three fifths of this vapor, that is, one hundredth of the whole elastic mass, was converted into water, then the heat given out would be sufficient to raise the temperature of the remaining mass of air and vapor six or eight degrees." * He also estimated the change in the bulk of the atmosphere due to a change of temperature. Mr. Daniell enlarged our comprehension of the subject, by showing the elevation necessary to the condensation of vapor at certain temperatures, and the manner in which the admixture affected the gradation of temperature resulting from the decreasing density of the upper parts of the atmosphere.

" The steam, [the slow and silent influence of which Daniell considers as one of the mainsprings of all the wonderful motions of the air and changes of the weather,†] as it reaches its point of condensation, must give out its latent heat, and during its precipitation, combining with a fresh proportion, it again ascends, and again evolves in the middle regions. It may thus be considered as carrying caloric from the surface of the sphere to the higher strata ; and it is obvious how a considerable section of any one column may thus have its temperature equalized and fully saturated with aqueous particles. The currents •thus become affected, both by the expansive powers of the vapor, and of the extricated heat." *

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* *Manchester Memoirs*, Vol. V., Old Series, pp. 523-525.

† *Meteorological Essays and Observations*, p. 263.

Thence it follows, that the condensation of elastic vapor into clouds raises the temperature of the air ; and this theoretical and practical conclusion is confirmed by the observation of M. de Luc, who found the thermometer to rise in a cloud. He noticed, also, that as the cloud became larger and more dense, it increased in elevation.† An accumulation of aqueous vapor, and a consequent unequal expansion of the atmospheric columns, are accompanied by a decrease of density, and are made known by a fall of the barometer. A constant stream then rushes in with increasing force, augumenting by its condensation the cause of its velocity.‡ Mr. Dalton, and afterwards Professor Leslie, demonstrated, that the mean temperature of the atmosphere diminishes from below upwards, in a regular gradation. This diminution has since been determined to be about one degree for every one hundred yards of ascent. Mr. Daniell discovered, that the elasticity of aqueous vapor does not decrease with the gradual decrease of the temperature and density of the air, as we ascend, but remains stationary at great heights.§ He also accounted for the apparent permanency and stationary aspect of a cloud. Clouds amongst mountains, and upon hills by the sea-side, appear to be perfectly immovable, although a strong wind is blowing upon them. The fact is, that the vapor, wafted by the wind, is precipitated by contact with the cold mountain ; and is urged forward in its course till, borne beyond the influence which caused its condensation, it is again exhaled, and disappears ; and this process must also take place on either side of the planes of precipitation in the atmosphere, and give an apparently fixed position to clouds in the free air.|| Gay-Lussac has also ex-

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* *Meteorological Essays and Observations*, pp. 77, 87, 129.

† *Ibid.*, pp. 101, 105. ‡ *Ibid.*, pp. 111, 112. § *Ibid.*, p. 128.

|| *Ibid.*, pp. 123, 124, and *Man. Mem.* Vol. V., New Ser.

plained the same phenomenon by the constant ascent of warm currents during the day. The theory of the formation of heavy masses of dense clouds, the *cumuli*, for instance, seen in fine weather, which sometimes accumulate in piles of stupendous magnitude and beauty, deeply shaded at the base, and terminating in lofty summits of silver lustre, is given by Daniell.* The sun dissolves the morning vapors, and, during the heat of the day, they rise from the surface of the land and waters, and reach their point of condensation in greater or less quantities at different altitudes.

> "And now the mists from earth are clouds in heaven;
> Clouds slowly castellating in a calm,
> Sublimer than a storm."

We have no room to devolope this hypothesis, but it is adopted by Mr. Espy, as one of the most striking illustrations of his theory. Dalton and Daniell had also provided invaluable helps to the meteorologist, in their very complete tables, exhibiting the specific gravity, elasticity, temperature, dew point, &c., of the atmosphere, at different altitudes, for every ten degrees of latitude from the pole to the equator.

Mr. Espy's combination of the foregoing facts and principles is equally novel and ingenious. The first formation of a cloud is occasioned, he conceives, by the uprising of a column or stratum of air from the surface, where it has become more heated, or more highly charged with aqueous vapor, and thus specifically lighter than the air in its vicinity. As this column ascends, it is cooled, by the expansion due to diminished pressure, at the rate of about one degree for every one hundred yards of ascent, allowance being made for the corresponding decrease in the elastic force of the vapor. If it rise high enough, the cold thus produced will condense some of its vapor into cloud. The highest temperature, at which this can take place, is the dew-point; and the height, therefore, which the uprising column must attain, before this condensation can occur, or the cloud be formed, depends upon the difference between the temperature of the air and the temperature of the dew-point, one degree of this difference answering to one hundred yards of altitude. As soon as the cloud begins to form, the latent caloric of the condensed vapor, being liberated, raises the temperature of the air in the column, and prevents it from cooling so fast in its further progress upward as it did to that point, keeping it constantly at a higher temperature, and consequently less heavy than the air of the surrounding region. An upmoving power is thus created, and rapidly increased by the latent heat, or caloric of elasticity, of the vaporous portion of the atmosphere in the column.

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* *Meteorological Essays and Observations*, p. 124.

This may be regarded as the first step of the process, and Mr. Espy thinks, that it is going on simultaneously in other parts of the atmosphere for many miles round, as appears from the number of detached clouds existing at the same time. All these columns have a tendency to approach and unite into one large cloud. A mechanical disturbance of the atmospheric equilibrium has now taken place, which nature will make efforts to restore. First, there must be a new accession of air towards the rarefied column, increasing its upward steam power ; secondly, the air, carried into the upper parts, is to be disposed of. The necessary supply is afforded by the rush of air on all sides towards the centre of the ascending column ; and here we have Mr. Espy's converging winds. We speak of this as the second step. The third is the disposition of the air in the upper part of the column. The great expansion of the air in the newly generated cloud will cause it to spread outward in all directions above. The outspreading of the air will form an *annulus* all round the cloud, in which the air will sink from its greater weight, and increase the velocity of the wind near the surface of the earth towards the centre of the column ; whilst, on the outside of the *annulus*, the pressure will cause a gentle wind outwards. The upmoving currents are now supplied by the air within the *annulus*, and that which descends in the *annulus* itself. Any general currents, that may exist at the time, will modify these motions by their transverse action, and may prevent the formation of the cloud, by breaking off and carrying away the highest portion of the column before it has reached the plane of condensation.

These are the fundamental propositions of Mr. Espy's theory, and in connexion with them, one important fact is to be specially noted. The ascending column originates in the smaller specific gravity of a stratum of air. As the column rises, the specific gravity continues to diminish according to the elevating power ; or rather, it is more proper to say, that the elevating power is wholly due to the loss of specific gravity caused by expansion, and the heat emitted by the vapor as it condenses. Therefore, the barometer must fall to its lowest level in the column, or under the middle of the cloud. And such is the observed fact. Sir John Herschel, and afterwards Sir David Brewster,* objected to Mr. Espy's theory, that the inward rush of air ought to make the barometer rise in the centre of a storm. These distinguished philosophers had not given to the subject the attention it deserves. The converging winds endeavour to restore an already disturbed equilibrium ; but no sooner do they arrive at the point where they deflect upwards, than *they* also lose their gravity by expansion and *calorification.* A hasty perception of Mr. Espy's misapplication of the principle of spouting fluids may have occasioned their mistake. This principle applies to the converging tendency of the surrounding air. Mr. Espy commits the error of applying it, also, to the ascent of the air in the column, which is owing to its buoyancy alone.†

We have yet to show how Mr. Espy's theory explains the common operations of nature. As the force of the ascending current increases, together with the quantity of condensed vapor, the cloud will change from the fleecy *cirrus*, or massy *cumulus*, to the black and threatening *nimbus*, when the moisture will be precipitated in the form of *rain.* The more elevated drops of rain may be forced up by the powerful draught, and be discharged from the *annulus* into the clear, cold air, whence, being frozen, they will descend to the earth as *hail.* As the centre of the spout passes over the ground, its lifting power may take up light substances, which will afterwards reappear in those *showers of dust*, *grain*, &c., which have excited the curiosity of the philosopher, and the terror of the superstitious. ‡ If the air is very hot below, while no cross currents disturb the perpendicular elevation of the spout, and the whole atmosphere is highly saturated with vapor, then the inward and upward motions will be very violent. The rapid diminution of pressure will lower the point of condensation until the base of the cloud touches the earth. In this case, we have the phenomenon known as a *tornado* on land, or a *water-spout*, at sea. In this, the rarefaction of the air is extreme ; passing over a building, it may cause a sudden expansion of the air within, which will blow out the sides and roof. If a tornado should be arrested in its progress by meeting a mountain, it would disgorge at once its accumulated weight of water and ice in one immense flood, that would cut its way down the side of the mountain, carrying with it the loose earth and stones, and leaving a deep gully to mark the track of its ruin. This is Mr. Espy's mode of accounting for the *meteoric waterfalls*, one of which overwhelmed the unfortunate Willey family in the pass of the White Mountains. As the air spreads out more rapidly above than it runs in below, the causes which occasion the first formation of a cloud, may enlarge the circuit of their influence, so as finally to embrace a region of considerable extent, the violence of their action increasing with its time and extent ; the meteor then becomes a *storm*, or *hurricane*, whose motion, *en masse*, is governed by the predominating upper currents.

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* *Edinburgh Review*, No. 138.

† Professor Peirce's Objections, *American Almanac* for 1843.

‡ A shower of grain took place in 1840, at Rajket, in Kattywar. The natives flocked to Captain Aston, to ask his opinion of this phenomenon ; for not only did the heaven's raining grain upon them excite terror, but the omen was aggravated by the fact, that the seed was not one of the cultivated grains of the country, but entirely unknown to them.

We must content ourselves with these general outlines of Mr. Espy's beautiful and original theory, regretting that want of space alone, and by no means a want of respect for its merits, compels us to withhold the further development of its details. "This beautiful mechanism, whether it has been adopted by nature or not, is most worthy of her, and Mr. Espy may honorably be proud of its conception."* The reception of this theory, by the French Academy, amounted to applause. A report upon it was made by a committee consisting of MM. Arago, Pouillet, and Babinet, names eminent in physical science, who, regarding Mr. Espy's facts as fully confirmed by his documents, and confiding in his observations, accepted his hypothesis in terms of the highest approbation. One qualification, and one prolific of doubts, was admitted ; it was, that Mr. Espy had not taken into account the effect of electricity in these phenomena.

Mr. Espy's "Paper on Storms" was read before the British Association, in September, 1840. It excited universal interest, and his lecture room was so thronged, that numbers were obliged to turn from the door, after a vain attempt to procure admission. Mr. Espy has subjected his theory to the rigid test of mathematical analysis, by computing, from the *data* of Dalton and Daniell, the amount of heat given out by the condensed vapor, the decrease of density in the ascending column, the effect of the diminished pressure upon the barometer, and the force and velocity of the upward motion. Among other objections made at the meeting of the British Association, it was stated by Professor Forbes, that these calculations were erroneous. We should have been content, without further examination, to reply, that the committee of the French Academy pronounced them "*tres suffisamment exactes*," had not Professor Peirce of Harvard University repeated them in one instance, and proved, that "there are cases in which rain does fall, and in which Mr. Espy's uprising columns cannot be sustained;" from which he concludes, that "his views do not embrace the whole subject, and some other mode of accounting for the continuance of the rain remains to be ascertained."*

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* "Espy's Theory of Storms," by Professor Peirce. *Camb. Miscellany*, No. 3.

Professor Forbes further objected, that the central funnel or spont would be insufficient to vent the air rushing into it. An upward motion, however, of ten miles an hour, in a space of moderate dimensions, such as is indicated by the calm in the centre of a storm, would give vent to air rushing towards it from every direction with the velocity of one hundred miles an hour. But this reply to Professor Forbes injures Mr. Espy's theory of the formation of hail. Mr. Arch Smith's remark, that a rotary motion must inevitably result from a centripetal one, unless we imagine the infinite improbability, that all the radial forces precisely counterbalance each other, is so plainly justified by an elementary principle of dynamics, that we wonder it escaped Mr. Espy's penetration. But to objections of a theoretical character, like these last, Mr. Espy answers by an appeal to facts, and the recorded phenomena of nature. Taking facts, then, as our argument, we intend to add a few comments.

In order that a theory may possess the requisite degree of plausibility, it ought not only to be correct in its fundamental principles, but sound and accurate in its deductions ; not only symmetrical in its general structure, but perfectly harmonious in its agreement with authentic observations. The primary principle of this theory leads its author to maintain, that artificial fires, by creating an ascending stream of heated air, under favorable circumstances, may produce rain. In the spirit of an adventurer rather than a philosopher, he offers to display this feat, if a promise of sufficient reward be given *in case of success.*[*]

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* *Cambridge Miscellany*, No. 3.

But the statements with which Mr. Espy enforces his opinions point also to the generation of electricity, by chemical decomposition arising from combustion, as a probable cause of the shower. If his theory were strictly correct, we might expect, that the heat communicated to the atmosphere by the combustion of fuel, and by the animal respiration in great cities, would prove a frequent source of rain.[†] Yet the table of Mr. Dalton shows, that less rain falls at London, Liverpool, and Manchester, than in the country. The amount at London is eight inches below the mean of Great Britain, as determined by Dalton. The meteorological observations throughout the Philosophical Magazine show the same result. One table exhibits the quantity of rain, for a series of years, in more than one hundred places in both hemispheres. The mean annual amount of the whole table is about 42.5 inches. The annual amount at London, according to Howard, is 25.2 inches ; according to Daniell, 22.2 inches ; and according to Dalton, from forty years' observation, 20.7 inches. The annual amount at Paris is 19.9 inches. We have already shown, that the centripetal tendency of the winds in a great storm, advocated by this theory, is contradicted by the facts. The whirling motion in whirlwinds, waterspouts, and tornados, also, is proved by the testimony of accurate witnesses. Mr. Espy thought so in 1833, before he had contrived his theory ; then he said, "When a waterspout occurs, it is acknowledged on all hands, and by every observer, that it is attended by a whirlwind."[‡] We may refer particularly to the descriptions of that able seaman and hydrographer, Horsburg, who, having prepared his ship, carried her through the centre of several of them.* The accounts of Captain Beechey, the report of the tornado that sunk the steamboat *Tigris* in the river Euphrates, on the 21st of May, 1836, and the observation of Colonel Reid, are distinct and explicit upon this fact.† M. Pellis, professor of mathematics in the college of Sainte Foy, describes a tornado that happened at Flanjaques. ‡ It turned a mill round, and twisted the trees, until their tops were forced round almost the entire circle. Several were noted in the last century, at the lake of Geneva, and Limay in France, of a similar character.§ And Mr. Espy, in his extracts from M. Peltier, has included a very striking instance of one, which devastated the *communes* of Fountenay and Châtenay, (near Paris,) during which "there arose a frightful whirlwind of dust, and light bodies." ‖ The same remark applies to the hurricane of Stow, described by Professor Loomis, to the New Haven tornado, by Professor Olmsted, and the Providence tornado, by Mr. Redfield. The only exception of weight is the New Brunswick tornado, the *traces* of which were carefully examined by Professors Bache and Henry. They did not witness the tornado itself. Their conclusion was, "that the effects indicated a moving column of rarefied air, without any whirling motion, at or near the surface of the earth." We shall not endeavour to set aside these high authorities, or take any thing from their valuable opinions in this particular case. Still, the whirling motion in the others remains to be accounted for, upon other principles than those of Mr. Espy's theory. But for authorities, we may cite the distinguished names of Pouillet¶ and Despretz,** both of whom speak of tornados as characterized by a whirling movement.

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[*] Espy, p. 497.

[†] Mr. Hutchinson's *Objections*, Espy, p. 463.

[‡] *Franklin Journal* for Nov. 1833.

The most minute and satisfactory relation of a whirlwind is to be found in a letter from Dr. Franklin to Peter Collinson.†† Franklin accompanied it three quarters of a mile; he found the "circular motion amazingly rapid, bending some tall trees round in a circle swiftly, and very surprisingly." This whirlwind, the tornado of 1741 at Lake Geneva, and that quoted from M. Pellis, were unattended with rain or hail. The latter left behind a dense smoke, that was not even moist. In these phenomena, Mr. Espy's steam-power is entirely wanting ; for he certainly will not ask us to believe, that the vapor was condensed, and that an ascending force, varying from two hundred and forty to seven hundred and twenty feet a second,[*] existed in the spout, and yet that no drops of rain should be thrown from its summit. Here, again, we have very striking phenomena, that are to be accounted for upon other principles than those of Mr. Espy's theory. His neglect of the influence of electricity, also, which he regards as only accessory and secondary, is, in our judgment, a fatal defect. His theory aims at a complete explanation of all the wonderful changes of the atmosphere, without a passing notice of this mighty agent. We are not aware, that there is any detailed description of a tornado, in which it does not appear to take an active part ; and several of those the most minutely and accurately portrayed, such as the tornado seen from Nice by M. Michaud,[†] those of Châtenay,[‡] Natchez, and Providence, exhibit its presence in so striking a manner, that it is difficult to imagine their production by other means. Dupré quotes the accounts of two tornados, which ravaged the vicinities of Pas-de-Calais on the 6th of July, 1822, and Trèves on the 25th of June, 1829, in both of which, the whirling motion and electrical agency are distinctly marked. He introduces them to teach the student the nature of these terrible storms.[§] Lamé also adopts Peltier's theory of the electrical origin of tornados.[||] Mr. Espy subsequently qualifies his opinions to this extent ; that he "would not be understood to say that electricity has nothing to do with this phenomenon" ; but still he regards "the dynamical agency, necessarily resulting from the diminished weight of a suddenly formed cloud," as the prime cause, both in order and effect.[¶]

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* Reid, p. 9. † *Idem*, chap. 11. ‡ *Comptes Rendus*, Vol. I.

§ *Histoire de l'Académie*, 1741, p. 20 ; 1742, p. 26 ; 1764, p. 32.

‖ Espy, p. 357. ¶ *Elémens de Physique et de Météorologie.*

** *Traité Elémentaire de Physique*, 4th ed. p. 865.

†† Franklin's *Works*, Sparks's ed. Vol. VI. p. 201.

We have yet stronger reasons for believing, that the action of electricity alone can account for the formation of hail.

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[*] Espy, p. 306.

[†] *Nicholson's Journal*, Vol. I. p. 583.

[‡] As described by M. Peltier.

[§] *Traité Elémentaire*, p. 368, Vol. I.

[||] *Cours de Physique*, 2d ed. Vol. III. pp. 98, 100.

[¶] Espy, p. 370. — The philosophic view of the electrical origin of tornados is ably presented by M. Peltier, "*Sur Trombes*," and by Dr. Hare of Philadelphia, in his reply to Professor Oersted of Copenhagen, in Reid's Appendix.

A particular kind of crackling is frequently heard before the descent of hail, attributed by some meteorologists to electrical discharges, a thousand times repeated, the hail-stones being strongly and differently electrified. On the approach of hail, the atmospheric electrometer affords another proof; the electricity is found not only to change in intensity, but to pass from positive to negative, and *vice versâ*, ten or twelve times in a minute.* Hail has been observed to fall from a cloud, that had previously discharged rain, when it encountered another cloud rushing towards it with great violence, and producing thunder. Some of the most beautiful provinces of France and Italy have been subject to periodical visitations of desolating hail storms, which have demolished the labors of the husbandman and vine-grower, and converted the bloom of summer, or the riches of autumn, into dreariness and sterility. Some places, from frequent catastrophes of this kind, have obtained the designation of "hail countries." Mr. Murray † relates several instances in which fields in these districts have been perfectly protected from the fatal consequences of these storms by conductors, or *paragrêles*. The hail cloud has carried its ravages to the very borders of the enclosure thus guarded, and, becoming harmless within the sphere of attraction of the *paragrêles*, has passed over it without injury, whilst it continued its work of destruction upon the adjoining plain, which had no means of disarming the cloud of its electricity.

We have still more important testimony from M. Lecoc, professor of natural history at Clermont-Ferrand, whose philosophic ardor carried him into the very laboratory of nature, when engaged in her mighty operations. He ascended the mountain of Puy-de-Dôme during a storm, and remained in the clouds which were pouring down rain and hail alternately. He observed, that both hail and rain, especially the former, were precipitated immediately after a flash, and seemed to be a consequence of the lightning. Another fact, bearing on our argument, was remarked, that the hail cloud was low. Mr. Espy, it will be remembered, in his theory, requires, for the phenomenon of hail, a lofty cloud and great ascending force in the spout, to raise the drops of condensed vapor to its summit, and discharge them into the cold air where they are congealed. M. Lecoc saw two distinct beds of clouds, separated by clear atmosphere. It was only when these clouds, brought near each other by contrary winds, were imposed one over the other, that the hail was formed. The flash invariably preceded its descent, and it always fell from the lower cloud. M. Lecoc was able to determine the height of these clouds, some of which were beneath his station. One was only twelve hundred metres, or about two thirds of a mile high.* The motion of the clouds is adverse to Mr. Espy's theory. They approached, overlaid, and passed beyond each other, *retaining their full shape*, and did not, according to his supposed law, converge to a space of general congregation, and there appear to rise. Mr. Espy's column, also, was variously scattered by the conflicting winds, and yet clouds were formed, and successive storms followed their conjunction. M. Arago testifies, that he has more than once seen clouds, from which hail would in a few moments have escaped abundantly, cover as with a thick veil the whole extent of a valley, whilst the neighbouring hills enjoyed at the same time a pure sky, and agreeable temperature.† According to Von Buch, it rarely hails on mountains, owing to the low elevation of the clouds from which hail descends. Finally, the illustrious Lamé, in unqualified language, ascribes to electricity alone the generation of hail.‡

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* Mr. George Harvey's *Treatise on Meteorology*, — *Encyclopædia Met.*

† *Treatise on Atmospheric Electricity*, by John Murray, F. S. A., &c. &c. pp. 131, 135.

We must terminate here our hurried examination of Mr. Espy's theory. Though it makes use only of principles of acknowledged validity, and is simple and elegant in the combination of them, we conclude, that their application is, in many cases, and with regard to the most interesting particulars, erroneous both in mode and degree. The actual phenomena of nature, the rotation of the winds in storms, the whirling motion of the tornado and water-spout, and the existence of these phenomena unaccompanied by the evidences of Mr. Espy's *only* cause of aërial disturbance, the terrible power of electricity, are not accounted for, or even recognized. How far he may find it necessary to modify it hereafter, we shall not undertake to decide ; "but whatever may be the result, the merit of having first noticed this tendency of the liberated caloric must be conceded to Mr. Espy, and never can be disregarded as unimportant in any correct theory of storms." *

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* *Comptes Rendus*, Vol. II. p. 324.

† Mr. Harvey's *Treatise*.

‡ Vol. III. p. 95. The formation of hail has been twice proposed by the French Academy, as the subject of an essay to receive the first mathematical prize, without success.

We have already had occasion to point out several inaccuracies of Mr. Espy, which seriously affect his character as a teacher of science. We should fail in duty to our readers, if we were to pass over some other errors, that have fallen under notice in the course of our investigation. In 1831, Mr. Espy declared, that he had found, by repeated experiments, that the dew-point descended before rain.† At that time, he advanced a different hypothesis concerning rain, based upon the independent motion of the particles of aqueous vapor, which he derived from Dalton's "Constitution of the Atmosphere." His present theory requires, that the dew-point should *rise* before rain ; accordingly, he tells us, that the air becomes highly charged with aqueous vapor before the cloud begins to form. The philosopher is allowed to alter, or abandon his hypotheses, and should be ready to do so, when he finds them inconsistent with facts ; but the facts themselves are not, we conceive, equally flexible and convenient. On two occasions, Mr. Espy specifies the height of the clouds, and furnishes the *data* by which his computations are made. One of these clouds he pronounces eleven,‡ and the other, fourteen,§ miles high, and he adds, (what ought to be very gratifying to our pride to know,) that the steam power of the clouds in the United States is much greater than it is in Great Britain. These astonishing altitudes so far exceeded any thing in the table of Crosthwaite, the actual measurements of Riccioli, or the observations of Humboldt and Dalton, that we were induced to repeat his calculations. We have too great a reverence for the mother country, step-mother though she be, to rejoice in any such unfair advantage over her ; we were, therefore, pleased to discover, that our formulæ reduced these ambitious elevations to four miles in the first instance, and to two and a half (!) miles in the last. In the first case, we counted the sunset from the setting of the upper limb ; but if Mr. Espy dated from the centre, as he probably did, the cloud would come down to less than three miles. In the latter case, we made allowance for the refraction and sun's semidiameter, without which any pretence to accuracy is frivolous. Mr. Espy assigned to these clouds velocities of forty-eight, and one hundred and twenty, miles an hour, respectively. We find the velocities to be eleven and thirty-two miles an hour.*

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* "Espy's Theory of Storms," by Professor Peirce. *Cambridge Miscellany*, No. 3. Mr. Meikle, of Edinburgh, claims the honor of having anticipated Mr. Espy in his theory ; (see *Edin. New Phil. Jour.*, Vol. XXIX.) For the proof, he refers to the "London Quarterly Journal of Science" for April, 1839, and to the article "Hygrometry," in the "Encyclopædia Britannica." We have examined this question ; and after observing, that Mr. Meikle's merit, or rather demerit, consists in having very imperfectly copied from Dalton, or Daniell, a single idea concerning the latent heat of vapor, we dismiss the claim with contempt.

† *Journal of the Franklin Institute*, for April, 1831.

‡ *Franklin Journal*, May, 1836.

§ *Philosophy of Storms*, p. 50.

The style of Mr. Espy's book demands some criticism. He has made an apology in the preface, (and one was needed,) for its ill sorted incongruities, and useless and costly repetitions. We will not, therefore, dwell upon this defect. Neither will we charge him with occasional injustice to Mr. Redfield.† Neither will we reproach him with his insufferable conceit and bad grammar, in calling his work "the beginning of our knowledge *on* the causes of Storms." ‡ after Dr. Franklin had discovered the law of progress of our northeast storms, and Mr. Redfield had established the law of rotation of the West India hurricanes, and Colonel Reid had published his valuable compilation of facts and observations, enriched by his comments. Neither shall it subdue our gravity, that Mr. Espy has been pleased to style himself, by implication, the Archimedes § and Newton || of meteorology ; or that he considers the modern chemists, who first discovered the latent heat of vapor, as holding the same relation to him, that the ancient mathematicians, who made the sections of the cone, may be supposed to have to Newton, Kepler, and La Place.¶

These things our charity can overlook. But his indecorous rudeness to a name illustrious in the annals of science imposes upon us a duty, which we hasten to perform. In

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* Mr. Espy, in his work, changes the altitude of the first of these clouds to ten miles, and its velocity to forty-five miles. The *data* remain unchanged. pp. 49, 50.

† *Philosophy of Storms*, Preface, and pp 58, 60.

‡ *Ibid.*, Introduction, p. 5.

§ *Ibid.*, Preface.

|| *Ibid.*, p. 438.

¶ *Ibid.*, pp. 24, 25.

treating the Huttonian theory of rain, Mr. Espy enters upon a calculation to show, that a rain such as fell at Wilmington on the 29th of July, 1834, of 5.1 inches, could not follow from the mingling of the whole atmosphere over that region, at extreme temperatures ; and he adds, " If gentlemen will frame theories on loose principles, without once putting these principles to the test of calculation, and without even taking the least notice of the latent heat of vapor, or the specific heat of air, they ought not to be surprised, that a little plain arithmetic should dissipate their empty visions, and 'leave not a wreck behind.' " *

Both here and elsewhere,† Mr. Espy has discreditably misrepresented Dr. Hutton's theory of rain. His " little plain arithmetic " assumes a case (that is, a still atmosphere), which would, if admissible, be just as fatal to his theory as to Dr. Hutton's. He knows, that such an objection as this is answered in all treatises on meteorology, by the great effect of variable winds in transporting the humidity of the air in every direction, and by numberless currents in every locality and at every altitude, blending together the vapor raised at diverse places, and thus producing, in accordance with the hypothetical principles, sufficient sources of more or less abundant precipitation. It is the mingling of currents from different quarters, and at various temperatures, which produces rain in Mr. Espy's theory. He suggests, that the concurrence of the winds obeys a certain law. Admit this law to be true, yet after the streams of converging air have met, nature will deposit their moisture according to laws discovered by Dr. Hutton ; and we regard his omission of Dr. Hutton's principle of the relative ratios of increase of the temperature of the air, and of the aqueous vapor, as a great oversight. But to speak of the hypothesis of Dr. Hutton, which, for forty years, has been accepted by the scientific men of Europe as the most plausible theory of rain ever invented, as an empty vision framed on loose principles, is language so indecently disrespectful to this profound mathematician, ingenious theorist, and skilful experimentalist, characterized as it is with the exultation of superior success, that it merits, and shall receive at our hands, the severest rebuke.

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* *Philosophy of Storms*, p. 444.

† *Ibid.*, p. 209.

We have no space left to fulfil our first intention of taking such extended notice of Professor Loomis's paper as its importance claims. It is elaborated with remarkable care and ingenuity, and — to give it a high praise — is worthy of its author. We trust we shall hear soon of the removal of this able inquirer to some university in the Atlantic cities, where he may take his proper place in the front rank of American science. To the subject before us, our scientific countrymen may turn with just and honorable pride. It has revealed new and valuable facts, and these facts are of that class which lead to the knowledge of general laws. It has served the great cause of civilization and humanity, by giving fresh security to navigation, and by imparting to the seaman new and useful guides, when he fearlessly steers his ship into the hostile regions of storms, —

> "And through the shock
> Of fighting elements, on all sides round
> Environed, wins his way, harder beset,
> And more endangered, than when Argo passed
> Through Bosphorus, betwixt the justling rocks;
> Or when Ulysses on the larboard shunned
> Charybdis, and by th' other whirlpool steered."

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ART. V. — 1. *An Address to the People of Rhode Island, delivered in Newport, May* 3, 1843, *in Presence of the General Assembly, on Occasion of the Change in the Civil Government of Rhode Island.* By WILLIAM G. GODDARD. Providence: 1843. 8vo. pp. 80.

2. *A Concise History of the Efforts to obtain an Extension of Suffrage in Rhode Island, from the Year* 1811 *to* 1842. By JACOB FRIEZE. Providence: 1842. 12mo. pp. 171.
3. *The Affairs of Rhode Island: a Discourse delivered in Providence, May* 22, 1842. By FRANCIS WAYLAND. Providence: 1842. 8vo. pp. 32.
4. *Charge of the Honorable Chief Justice Durfee to the Grand Jury, at the March Term of the Supreme Judicial Court at Bristol, R. I.* 1842. 8vo. pp. 16.
5. *A Review of Dr. Wayland's Discourse on the Affairs of Rhode Island; a Vindication of the Sovereignty of*